SANDIA REPORT
SAND2006-1760
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Printed March 2006

CABLEGEN: A Program that Automatically Generates CUBIT Journal Files for Meshing Coaxial Cables Version 1.0

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Abstract

The CABLEGEN C++ program has been developed to automate the process of developing a CUBIT journal file for coaxial cables with and without air gap defects. This program is part of the coaxial cable design simulator that is currently under development.

1 ACKNOWLEDGMENTS

This work was supported by the US Navy Strategic Systems Program Office under contract No. N000-30-99-G-0039.

2 CONTENTS

3 FIGURES

4 TABLES

5 NOMENCLATURE

ASC	Advanced Simulation Computing program at NNSA
C++	Computer language
CUBIT	Sandia developed meshing tool
DOE	Department of Energy
GUI	Graphical User Interface
SNL	Sandia National Laboratories

1 INTRODUCTION

The "Design Simulator" effort has been underway at Sandia National Labs for several years. The goal of this effort is to develop and deliver a completely integrated and easy to use modeling capability targeted, typically, to a specific capability or component. Key to this effort is making this modeling capability readily accessible via the standard desktop computer.

The actual modeling capabilities incorporated into a design simulator range from simple analytic models characterized by running on a single processor computer to the high fidelity finite element models represented by the ASC codes. In any case, a design simulator includes the ability to fully define the problem of interest (geometry, meshes, materials, loads, etc.), submit the entire job including post-processing to a remote computing resource, and ultimately to visualize and access the results via the desktop computer.

Many design simulators have been deployed at Sandia, including for example, several neutron generator simulators, an earth penetration simulator, a thermal battery simulator, an ESD simulator, etc. In numerical modeling employing finite element analysis capabilities, mesh generation is a critical component of the process. In fact, it is often times the key bottleneck in the modeling process. Thus, for the design simulators incorporating finite element analysis, a fully automatic meshing capability is an absolute necessity.

In the above vein, an effort to develop and deploy a finite element based coaxial cable design simulator, capable of treating certain manufacturing defects like air gaps, was initiated in late FY04. Efforts initially focused on the very important definition and the implementation of the graphical user interface (GUI) that the user interacts with. In FY05, refinement of the GUI continued, but the majority of the work has focused on the underlying analysis process.

In regards to the mesh generation portion of the analysis process, early attempts at automating the meshing of a coaxial cable, including air gap manufacturing defects, had relied on the traditional approach of developing a parameterized CUBIT[1] journal file. Here, the model parameters, such as the radii and material identifiers of the various layers and the air gap definition, were assumed to be found in a text file. This file would automatically be written by the design simulator and "included" in the CUBIT journal file.

Several problems were observed with this approach including the limited nature of the cable and air gap definition, the extreme element count of the meshes generated, and the excessive time needed to generate the meshes. In addition, the complexity of the journal file was extreme with the effort producing a nearly 100 page long journal file. This potentially made the job of maintaining or enhancing the journal file difficult.

Having observed the above difficulties, a different approach was suggested. This new approach was based on the idea of a so-called "2-pass meshing scheme" implemented via a C++ program, that would address the previously discussed issues. In essence, the C++ program would read the previously discussed parameter file, followed by automatically creating (writing) the required CUBIT journal file. This approach had previously proved successful in, for example, the thermal battery simulator, with the primary difference being the idea of the second pass. The passes in the new approach can easily be thought of as 1) modeling the rather simple geometry and 2) capturing the interesting physics that typically occurs between different material layers, respectively.

This approach of writing a C++ program that generates a CUBIT journal file had previously proved robust in handling the case where topology was being altered, as embodied in the idea of more general coaxial cable and air gap definitions. This is in contrast to the approach of writing a parameterized CUBIT file which has worked better for constant topology problems, such as in the neutron generator design simulators.

The balance of this document focuses on generally describing the process codified in the CABLEGEN C++ program. In particular, we generally describe the activities pursued in each of its three modules, namely the *get_data*, the *make_cable*, and the *make_airgap* modules.

2 THE CABLEGEN INTERFACE

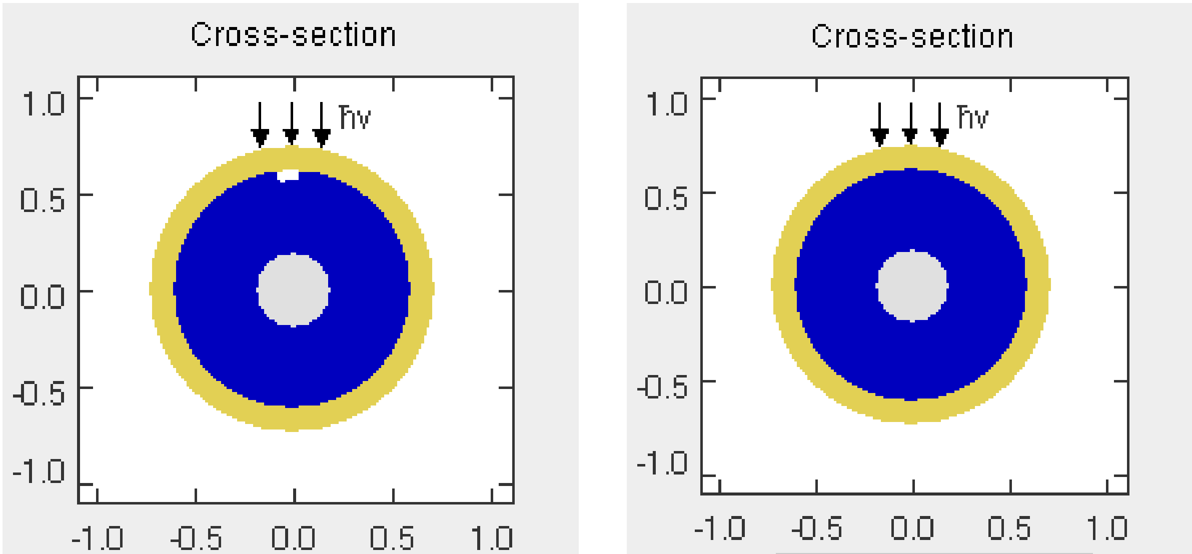
In the context of the interface between the coaxial cable design simulator and the CABLEGEN program, we confine our description to the required CABLEGEN input file. As previously mentioned, this file is assumed to be automatically written by the coaxial cable design simulator. In fact though, this rather simple file can be constructed in any manner and beneficially used. The transparently coded *get_data* module, called by the main program, is completely responsible for reading the input file and echoing the individual parameters read.

Geometrically, a coaxial cable can be thought of as a cylindrical tube composed of a varying number of annular layers of different materials. During manufacture or assembly of the layers, defects may be inadvertently introduced. More specifically, air gaps may be introduced between or within the layers of the coaxial cable. These air gaps can adversely affect the desired performance of the cable in some extreme environments.

Because of the complexity of the analysis, only the two-dimensional cross section of a coaxial cable is considered in the coaxial cable design simulator. Furthermore, the geometric definition of an air gap has been limited to be a uniform section of at most two adjacent annular layers that lie within at most a quarter-section of the cable.

Thus, the geometric definition of a coaxial cable, including an air gap, consists of the number of layers that the coaxial cable is composed of, the radius and material identifier of each layer, an indicator as to whether an air gap is located in that layer, the angular extent of the air gap, and the initial angular location of the air gap relative to the standard positive y axis. Finally, some meshing specific information, namely the element type to be used, the minimum element size, and an element aspect ratio are also contained in the file.

More specifically the parameters read, a short description, and their allowable values are contained in Table 1 in the Appendix at the end of this document. Each row in the table represents the information that must be contained in that line. The lines, and the parameters within a line, must be read in exactly the order indicated. In line 2, the text line contains three parameters related to the definition of an individual layer in the cable. Each parameter in this line must be separated by at least one blank space. Line 3 of the file contains information related to the types of elements generated. Two parameters are read on the line without any character between them. Examples of the input decks and pictures of the corresponding coaxial cables, with and without an air gap, are shown below in Figure 1.



4		
4.57E+02	1	1
1.32E+03	1	2
1.44E+03	-1	2
1.73E+03	1	11
Q8		
0		
10		
4		
1		

3		
4.57E+02	1	1
1.44E+03	1	2
1.73E+03	1	11
Q8		
0		
0		
4		
1		

Figure 2-1 Samples of coaxial cables with and without an air gap, including their corresponding input decks.

2.1 Cables without an Air Gap

We first consider the case of generating a finite element mesh for a coaxial cable *without* an air gap. The case of generating a finite element mesh for a coaxial cable *with* an air gap is an extension of this simpler case. The entire process of geometry creation, mesh generation (first and second pass), and material and boundary condition specification is accomplished in the *make_cable* module of the CABLEGEN program. This module is activated through the main program. As an example, the quarter section mesh produced for the coaxial cable without an air gap shown in Figure 1 (using the displayed input deck) is shown below in Figure 2.

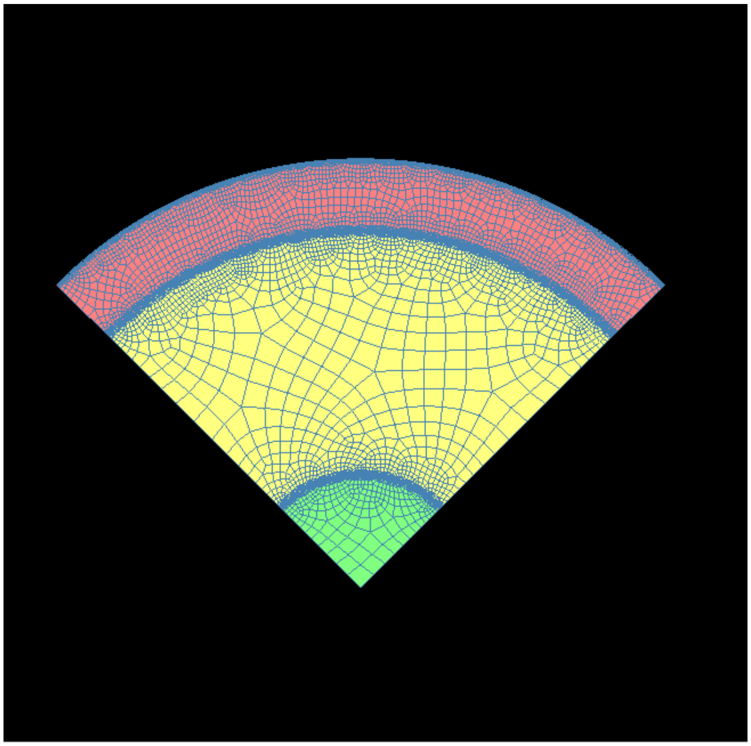


Figure 2-2 The quarter section mesh for the coaxial cable without an air gap, shown in Figure 1.

2.1.1 Geometry Creation

The inner core of a coaxial cable, without an air gap, is geometrically defined as a cylinder with the appropriate radius. Each succeeding material layer of the coaxial cable is then defined as the resulting annulus generated by geometrically subtracting a cylinder with the correct inner radius from a cylinder with the correct outer radius. For several reasons, namely meshing efficiency and the assumption that the air gap lies in at most a quarter section of the coaxial cable, a 90 degree section of the geometry is then extracted. This is accomplished by geometrically intersecting the entire coaxial cable geometry with an appropriately sized and positioned cube. Finally, the remaining geometry and topology are "imprinted and merged".

2.1.2 Mesh Generation

The first pass of the 2-pass meshing scheme is completed by meshing the above quarter section of the coaxial cable. It has been assumed, in general, that an eight (8) micron resolution is adequate to geometrically represent the coaxial cables of interest. Thus, an 8 micron size is specified on each surface of interest in the quarter section. Meshing is then accomplished resulting in either triangular or quadrilateral elements via the available CUBIT trimesh or paving schemes, as driven by user input.

If a resolution smaller than 8 microns is required for capturing the physics, then the second pass of the 2-pass meshing approach is activated. Currently, the elements along any curve between regions of different materials are split appropriately to achieve the desired resolution. This approach has the advantage of keeping the refinements local to material interfaces, and thus keeping the total element count at a minimum.

To further conserve on the total number of elements generated, it is possible to specify an aspect ratio larger than 1.0 that effectively creates longer and skinnier elements along the interfaces between the regions. This initially occurs during the first pass of the 2-pass meshing scheme. The effect is propagated if further refinement, i.e., element splitting, is required.

2.1.3 Material and Boundary Condition Specification

The construction of the model is completed with two final steps: 1) specification of the "block and side set" identifiers, and 2) creation of the remaining three-quarters of the model. The latter is achieved by rotating the above completed quarter section three times, by 90 degrees each time, and writing those files. The result is four files (Cable1Q.gen, Cable2Q.gen, Cable3Q.gen, and Cable4Q.gen) that are then consolidated via a subsequent GJOIN[2] process. It should be noted that these files will be identical in size.

Although not detailed here, care has been taken within the CABLEGEN code to ensure a good GJOIN process by ensuring the same number of elements and the same element distribution on the two radial arms of the quarter region.

2.2 Cables with an Air Gap

As previously mentioned, the case of a coaxial cable with an air gap is considered an extension of the case of a coaxial cable without an air gap. In particular, since it is assumed that the air gap is confined to lie in one quarter of the cable, the three quarters of the coaxial cable model that do not contain the air gap are generated exactly as previously discussed. This results in the Cable2Q.gen, Cable3Q.gen, and Cable4Q.gen files.

We now consider the quarter section containing the air gap. As illustrated in Figure 1, an air gap is geometrically defined as a circumferential section of at most two adjacent annuli. Thus, to begin with, the geometry of the air gap is generated by defining the vertices of the annular section, including the necessary midpoints on the circular arcs. Then, using the above defined points, the corresponding curves are generated. Finally, the surface enclosed by the above curves is defined.

Next, the geometry of the quarter section of the cable containing the air gap is generated exactly as discussed in the case of a coaxial cable without an air gap. Then all of the geometry and the topology, including that of the air gap, is imprinted and merged, as before.

The remaining process for completing the finite element model of the quarter section of the coaxial cable containing the air gap is similar to that described in the previous section. That is, the first pass of the 2-pass scheme meshes the geometry to an 8 micron resolution level. Then, refinement to the required level to capture the physics between material layers is achieved by splitting the elements along the curves between layers of different materials. This specifically includes the curves between the air gap and the rest of the coaxial cable. Finally, the model is completed as before by specifying the required block and side set identifiers and ultimately writing the model to the CABLE1Q.gen file.

Here again, care has been taken to ensure a good subsequent GJOIN process by ensuring the same number of elements and the same element distribution on the two radial arms of each of the quarter sections. The entire process of geometry creation, mesh generation (first and second pass), block and side set identification, and file writing for the quarter section containing the air gap is accomplished in the *make_airgap* module of the CABLEGEN program. This module is executed from within the *make_cable* module.

As an example, the quarter section meshes produced for the coaxial cable with an air gap shown in Figure 1, using the displayed input deck, are shown in **Figure 3.** Finally, it should be noted that in this case with an air gap, the CABLE1Q.gen file should be larger than the other three files because of the extra elements around the air gap.

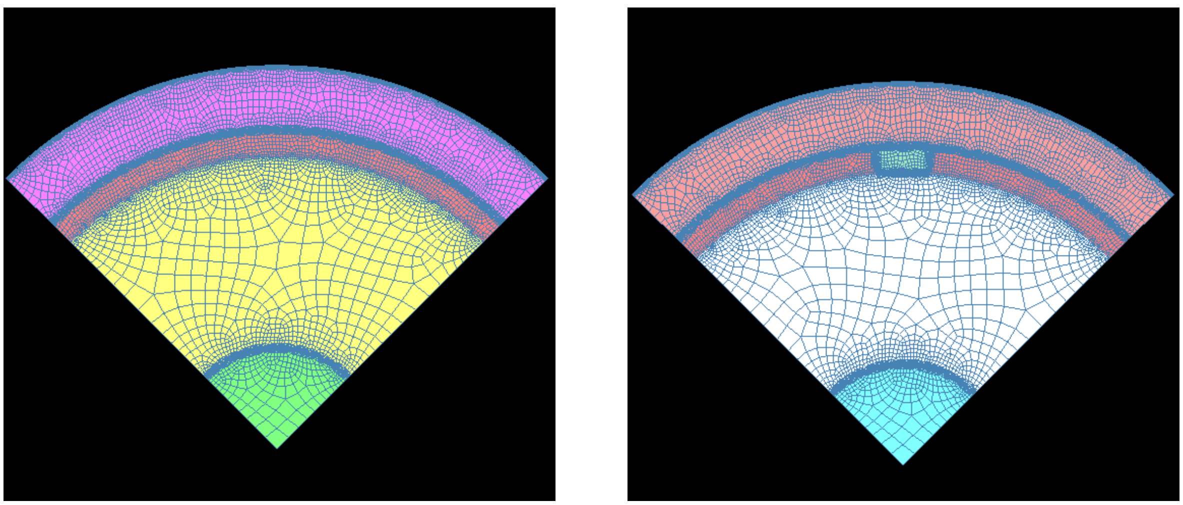


Figure 2-3 The quarter section meshes for the coaxial cable with an air gap, shown in Figure 1.

3 SUMMARY

The CABLEGEN C++ program has been developed to automate the process of developing a CUBIT journal file for coaxial cables with and without air gap defects. This program is part of the coaxial cable design simulator that is currently under development.

The finite element models produced consist of either linear or quadratic quadrilateral or triangular elements. Meshing is accomplished using a 2-pass scheme, where the first pass captures the geometry while the second pass, if necessary, addresses physics resolution issues by refining the elements along different material interfaces.

The models created are complete in terms of material and boundary condition specification. Because of a high degree of symmetry and consideration for meshing efficiency, the entire coaxial cable model is developed as four individual quarter sections. These quarter sections must be merged in a subsequent process, say using the GJOIN computer program.

4 REFERENCES

1) CUBIT Mesh Generation Environment, Volume 1: Users Manual, CUBIT Development Team, Sandia National Laboratories, SAND94-1100, April 2000

2) GJOIN:A Program for Merging Two or More GENESIS Databases, Gregory D. Sjaardema, Sandia National Laboratories, SAND92-2290, December 1992

5 APPENDIX

Table 1 Description of the CABLEGEN input deck.

Line	Parameter	Description	Values
1	nLayers	A positive integer indicating the number of layers, including the core, found in the coaxial cable	1 ≤ nLayers ≤ 50
2		Line 2 is read nLayers times	
	radius	A positive real number indicating the outside radius of the current layer of the coaxial cable, measured in microns.	Any positive, real number.
	newLay	An integer indicating whether the current layer contains an air gap or not.	newLay =1 if the layer does not contain an air gap. newLay = -1 if the layer contains the first layer of an air gap. newLay = -2 if the layer contains the second contiguous layer of an air gap.
	blockID	An integer indicating the block identifier of this layer of the coaxial cable.	Any integer.
3	elType	An alphanumeric character indicating the element type to be generated.	T for triangles or Q for quadrilaterals.
	elNodes	An alphanumeric character indicating the number of nodes associated with each element generated	If elType is T, then elNodes is either 3 or 6. Otherwise, elNodes is either 4 or 8.
4	angleV	In coaxial cables with an air gap, angleV is the real number indicating the angular location of the air gap, measured in degrees, of the air gap relative to the standard positive y (vertical) axis	Any real number.
5	angleW	In coaxial cables with an air gap, angleW is the positive real number indicating the angular width, measured in degrees, of the air gap.	5 ≤ angleW ≤ 85

6	elSize	A real number indicating the minimum element size of the elements generated, measured in microns.	Allowable values for elSize are 8, 4, 2, 1, and 0.5.
7	aspectRatio	A positive real number indicating the aspect ratio of the elements generated. The total number of elements generated is inversely proportional to this number. An aspectRatio greater than 1.0 creates elements that are typically longer and skinnier with respect to the radial arcs of the layers of the coaxial cable.	$0.0 \leq$ aspectRatio

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